Dieback in the Native Shrub, *Lindera benzoin*: A Subtle Effect of Forest Fragmentation[1]

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ABSTRACT. I report on a documented dieback in spicebush, *Lindera benzoin*, after the winter of 1993-1994 in two mature deciduous forest stands in southwestern Ohio. The study compares differences between 67 ha Hueston Woods and 5.2 ha Kramer Woods and examines spatial patterns of decline in Kramer Woods. Local daily minimum temperatures in January 1994 were among the coldest on record since 1889. The shrub is one of the most important understory species in both forests, but relative basal area measures of dead stems were significantly less in Hueston Woods (mean = 54% of the total) than in Kramer Woods (86%). Spicebush shows a clustered distribution in Kramer Woods, present on a flat upland area along the northern edge. Only two points with spicebush showed no decline and they are >60 m from the north edge and along streams. Dieback was up to 100% for plots with mean shrub heights >1.5 m, resulting in a significant understory gap. These findings identify important differences between and within forest patches that appear attributable to fragmentation effects. Forest conservation plans need to better capture a diversity of topographic settings or incorporate buffer zones along edges to better ensure the protection of native flora in human-dominated landscapes.

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INTRODUCTION

Southwestern Ohio is in the southern portion of the beech-maple association in the eastern deciduous forest (Braun 1950). The potential vegetation varies in response to topography and soil conditions, but on optimal settings north of the glacial boundary, beech (*Fagus grandifolia*) and sugar maple (*Acer saccharum*) are dominant in the forest canopy (Braun 1950, Vankat et al. 1975). Spicebush (*Lindera benzoin*) is characteristically the dominant understory shrub (Braun 1950).

Post-European forest clearing of the eastern deciduous forest was nearly complete in its magnitude before the early 1900s (Williams 1989, Whitney 1994). In the beech-maple association, intensive row-crop production with the rise of the corn belt isolated small forest fragments in a matrix of agricultural lands (Hart 1986). Curtis (1956) in southeastern Wisconsin, Whitney and Somerlot (1985) in central Ohio, and Medley et al. (1995) in southwestern Ohio document >90% loss with settlement and only a slight increase to less than 20% forest cover. Current forest cover in the southwestern part of the state is estimated at 14% (Griffith and Wharton 1994). Intensive and highly productive agriculture, coupled with urban expansion, maintain a very low distribution of forest (remnant or emergent) within the original mapped boundaries of the beech-maple association.

The ecological consequences of fragmentation are profound as large contiguous forests are converted to small isolated patches (see papers in Burgess and Sharpe 1981, Godron and Forman 1983). Abrupt forest edges alter microclimatic conditions and the relative competitive abilities of shade intolerant and tolerant species (Saunders et al. 1991). For instance, the greater light availability of small forest fragments or disturbed mid-successional woodlands may explain the success of the Asian shrub *Lonicera maackii* (Amur honeysuckle) in southwestern Ohio after about 1960 (Luken 1993) and European herb *Alliaria petiolata* (garlic mustard) in forests throughout the midwest (Nuzzo 1993). Human-related disturbances may provide windows for invasion and available habitats for establishment by nonnative plants (Hobbs and Huenneke 1992). The actual creation of an edge and adjacent land-use activities may be viewed as direct human-related disturbances. A more subtle concern, however, is the degree to which fragmentation may influence the "natural" disturbance regime of beech-maple forests.

I documented dieback in spicebush, *Lindera benzoin*, after the winter of 1993-1994 at two locations in southwestern Ohio. Spicebush is known to be susceptible to winter-minimum temperatures (Braun 1961), so its decline after a harsh winter may be viewed as a natural disturbance. The study first compares differences between the relative importance and dieback of spicebush in two forest patches: Hueston Woods, a 67 ha remnant stand, and Kramer Woods, a 5.2 ha regrowth stand that is at least 100 yrs old. Second, it examines spatial patterns of abundance and dieback in spicebush within a forest patch, Kramer Woods. Significant differences in the level of dieback between these two forests or spatial irregularities within Kramer Woods may suggest fragmentation effects. Land conservation plans need to carefully consider the impacts imposed by fragmentation when determining the size and position of a nature reserve in an otherwise human-modified landscape (National Research Council 1993). By focusing on the potential impacts of low-temperature extremes, this study examines one disturbance that may be indirectly influenced by the landscape position of a forest fragment.

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MATERIALS AND METHODS

Study Area

Two protected forest areas were selected that are less than 10 km apart and occupy similar physical settings on upland till-plain in southwestern Ohio (Fig. 1). Hueston Woods is an approximate 67 ha uncut forest stand protected in Hueston Woods State Park, Preble County, Ohio. The forest, especially its eastern sector, has remained essentially undisturbed since its purchase by the Hueston family in 1797 and acquisition by the State of Ohio in 1940 (Runkle et al. 1984). Kramer Woods is a much smaller, about 5.2 ha, forest stand that is protected as a natural area on the campus of Miami University, Butler County, Ohio. The forest is an old regrowth stand, at least 100 years, that was protected by the Kramer family and then donated to the university in 1989. These two forest stands differ significantly in size, but both have a long history of protection and now serve as nature reserves in the beech-maple association.

Climatological Record

The study focused on vegetation response after the winter of 1993-1994. Minimum winter temperatures were recorded at the Ecology Research Center, adjacent to Kramer Woods. During January and much of February, minimum temperatures were significantly below the mean minimum for the station (Fig. 2). Daily departures in January 1994, while not as sustained, were comparable to measures obtained during 1977, the coldest winter on record since 1889.

Vegetation Data and Analyses

In 1993, I began a long-term study of vegetation dynamics and nonnative plant invasion within Kramer Woods. Using a stratified-random approach, seven transects were placed east-west at no less than 25 m and no more than 50 m apart and sample points were located at 20 m intervals (n = 60; Fig. 3). The diameters at breast height (dbh) of all trees >10 cm dbh were measured in 9 x 12 m (108 m^2) plots, and trees <10 cm dbh were measured in nested 6 x 4 m (24 m^2) plots. I also measured in the smaller plots the number of shrubs that visually originated from a separate root base (i.e., individuals), their heights, and the basal diameters of their respective stems. In May-June 1994, I remeasured all spicebush in

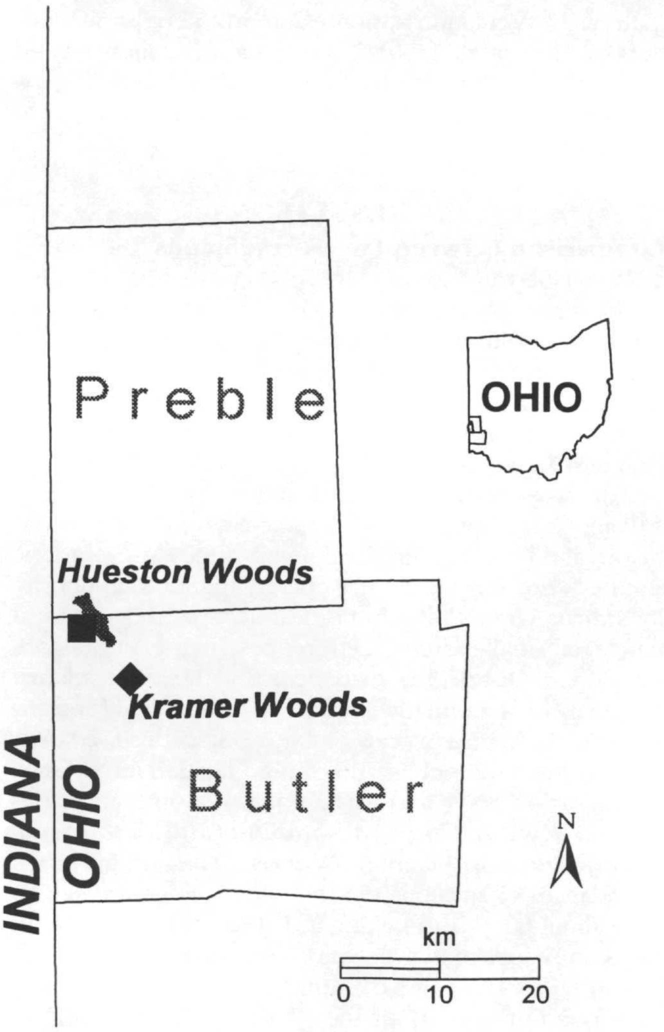

FIGURE 1. Location of the two forest study areas, Hueston Woods and Kramer Woods, in southwestern Ohio.

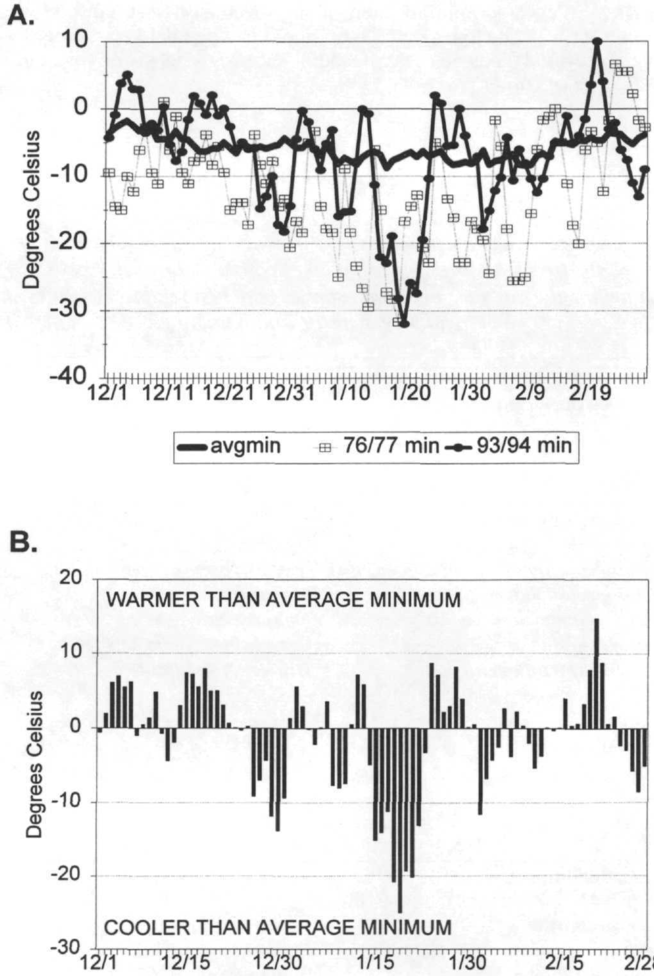

FIGURE 2. Winter minimum temperatures showing: (a) the daily minimums measured at the Ecology Research Center for the winters of 1976-1977 and 1993-1994 as compared with averages for Southwest Ohio (Division 08, National Climate Center Data); and (b) daily departures from the average minimum for the winter of 1993-1994.

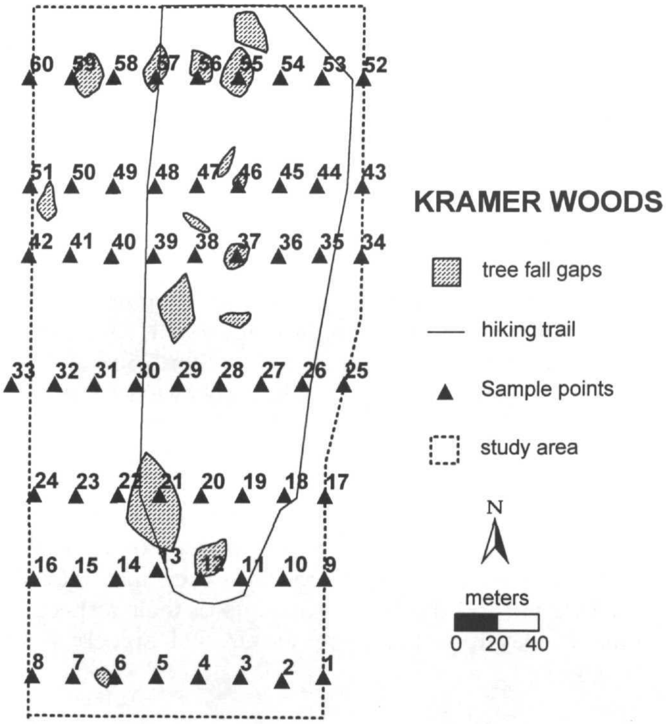

FIGURE 3. Vegetation plot locations along seven east-west transects in Kramer Woods. The forest patch is bordered by open field on the north edge, cultivated fields on the east, south, and west edges, and forest in the southeast corner.

TABLE 1

Species importances in the canopy (>10 cm dbh) and understory (<l0 cm dbh trees and shrubs) at Hueston Woods and Kramer Woods. Listed are the five most important species based on relative measures (%) of frequency, density, and basal area.

Hueston Woods		Kramer Woods	
Large Trees >l0 cm dbh			
Relative Importance (%)		Relative Importance (%)	
Acer saccharum	32	*Acer saccharum*	15
Fagus grandifolia	28	*Fraxinus americana*	12
Fraxinus americana	10	*Juglans nigra*	10
Prunus serotina	9	*Carya cordiformis*	8
Liriodendron tulipifera	3	*Liriodendron tulipifera*	6
Species Richness	7	Species Richness	23
Total Density	236/ha	Total Density	407/ha
Basal Area	21.3 m^2/ha	Basal Area	28.6 m^2/ha
Trees <10 cm dbh and Shrubs			
Relative Importance (%)		Relative Importance (%)	
Acer saccharum	40	*Lonicera maackii*	24
Prunus serotina	13	*Fraxinus americana*	12
Fagus grandifolia	12	*Acer saccharum*	12
Lindera benzoin	12	*Viburnum prunifolium*	9
Fraxinus americana	10	*Lindera benzoin*	7
Species Richness	13 spp	Species Richness	34 spp
Total Density	10860/ha	Total Density	12955/ha

the forest, recording the number of plots with spicebush that showed dieback, the basal area of stems that were live and dead, and the presence of new basal sprouts. For comparison, two transects were randomly placed in 1994 to run north-south through the east, flat-upland sector of Hueston Woods between the entrances to the Blue Heron and Sugar Maple Camp parking areas. I followed the same sampling procedure used in Kramer Woods except that the points were at 40 m intervals ($n = 17$).

Vegetation data from the sample plots were pooled in order to compare the two forests based on species importances (relative density, frequency, and basal area) in the canopy and understory. Dieback in spicebush was measured by the relative number of plots that showed and did not show dieback and the relative basal area of dead stems. The nonparametric Wilcoxon Two-Sample Test was computed to statistically test differences in the levels of dieback between the two forests, without making assumptions about the homogeneity of variances (Sokal and Rohlf 1981). Additionally, for Kramer Woods I used a geographic information system to examine spatial patterns of spicebush abundances and dieback within the forest patch. Sampling-point data were converted to raster-based Theissen polygons. This approach assumes that the characteristics around a point (about 20-30 m) are most like that point and that the spatial patterns in vegetation attributes are not necessarily continuous (Burrough 1986). These data were then related with intraforest locations of expanded tree-fall gaps (Runkle et al. 1984; Fig. 3) and measured mean slopes at each plot.

RESULTS

Comparison Between Two Forest Stands

Both Hueston and Kramer Woods were representative of the structure and composition of mature deciduous forests in southwestern Ohio (Table 1). The forest canopy in Hueston Woods showed a greater dominance by beech (*Fagus grandifolia*) and sugar maple (*Acer saccharum*), and had only seven tree species >10 cm dbh. Kramer Woods was more characteristic of a mixed-deciduous stand with a greater species richness of trees >10 cm dbh (23) and less importance attributable to sugar maple and beech. Total basal areas, a measure of forest stature, were similar, but the notably higher total density in Kramer Woods (407/ha) did indicate a greater abundance of smaller trees. Differences in the understory were more distinct, as evidenced by the high relative importance of nonnative Amur honeysuckle (*Lonicera maackii*) in Kramer Woods (Table 1). Spicebush, *Lindera benzoin*, was the only shrub of high relative importance in Hueston Woods, and was among the top three shrub species (with *Lonicera maackii* and *Viburnum prunifolium*) in Kramer Woods. The height-class abundances of spicebush in the two forests were similar with about 60% >1 m height and 40% <1 m in height. In Hueston Woods, however, spicebush was more common, occurring in 13 of the 17 sample plots (76%) where it was found at only 27 of the 60 sample plots (45%) in Kramer Woods.

In both forests, all plots that showed evidence of stem mortality also had live material above-ground or in the form of basal sprouts. The short-term impact of the cold minimum temperatures was to induce a dieback in the shrub. Plot measures in Hueston Woods documented a much lower amount of dieback in spicebush than in Kramer Woods. In Hueston Woods, I measured dieback in 8 of the 13 points with spicebush (62%), and of a total 0.26 m^2/ha stem basal area, 0.14 m^2/ha or 54% was measured as dead. In Kramer Woods, I recorded dieback in 25 of the 27 points (93%), and of a total 0.28 m^2/ha stem basal area, 0.24 m^2/ha or 86% was recorded as dead. The calculation of the Wilcoxon Two-Sample Test showed a statistically significant difference in the levels of dieback (% basal area dead) between the two forests (U_s = 247; prob. <0.03).

Spatial Patterns within a Forest Stand

Spicebush shrubs were clustered in the north sector of Kramer Woods (Fig. 4). This region corresponded with a flat upland area, suggesting a preference for low slopes. The mean slope for plots with spicebush was 5.1°, and 60% of the plots were on slopes less than the forest mean of 7.5°. In contrast, plots without spicebush have a mean slope of 10.0°, and 60% of these plots were on slopes greater than 7.5°. The clustered distribution of spicebush on the low slope area in the north half of the forest patch may partially explain the high dieback in Kramer Woods as it compared with Hueston Woods. Points 15 and 36, located greater than 60 m away from the north edge and on slopes off the upland, showed no dieback (Fig. 3). I measured <10% dieback at point 47 and its location is in the interior of the spicebush cluster. The stem basal area of spicebush in tree-fall gaps (0.71 m^2/ha) was not much different from the forest area outside of gaps (0.66 m^2/ha). A higher percentage of

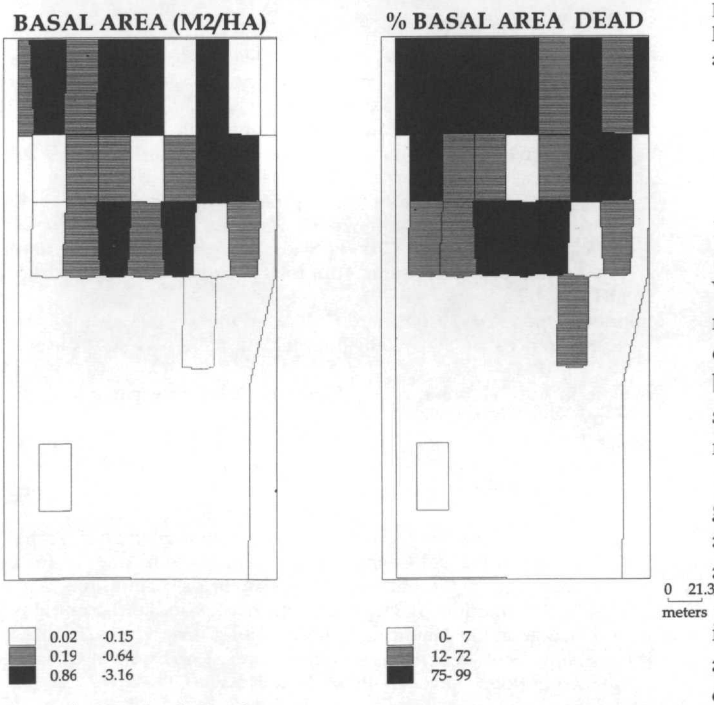

FIGURE 4. Spicebush distribution and dieback in Kramer Woods. The left map shows the stem-basal areas of spicebush measured at each point and the right map shows the percentages of the total stem-basal area that was recorded as dead. Sample point locations are shown in Fig. 3.

dieback within gap openings (93.1% versus 87.6% of stem basal area) may be partially explained by five mapped gaps within 40 m of the north edge (Fig. 3).

Dieback in spicebush within Kramer Woods was generally greatest for the larger individuals as measured by mean shrub heights in a plot (Fig. 5). All plots with a mean height of >1.4 m experienced >80% mortality except for plot 15 and plot 27, both located off the north upland in stream gullies. Plots with a mean height >1 m had 78% dieback in stem basal area, whereas plots with a mean shrub height <1 m had 57%. These results show that larger stems, especially along the northern edge, were particularly susceptible to the damage imposed by low minimum temperatures. Whereas greater mortality was also measured for plots in Hueston Woods with a mean shrub height >1 m (52%) versus plots with a mean shrub height <1 m (33%), the dieback percentages for both height classes were less.

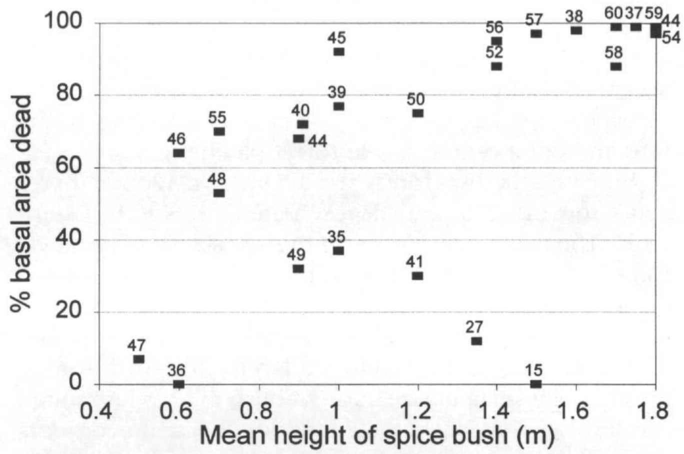

FIGURE 5. Scattergram plot showing the relationship between the mean height of spicebush measured in a vegetation plot and the % stem basal area measured as dead. Sample point locations are shown in Fig. 3.

DISCUSSION

Low minimum temperatures during the winter of 1993-1994 correspond with high dieback in spicebush, *Lindera benzoin*, in two deciduous forests of southwestern Ohio. While these findings are not contradictory to the documented ecology of this shrub (Braun 1961), the significant differences in the relative percentages of dieback between Hueston Woods and Kramer Woods, and the spatial patterns within Kramer Woods do suggest fragmentation effects.

Hueston Woods is one of the largest remaining old-growth stands in this region and is bordered by secondary forest to the east and old-growth forest to the north and west of the study area (compare Ray and Vankat 1984). The sample area is located mostly on flat upland in an area of little known disturbance from human activities (Runkle et al. 1984, Vankat et al. 1975). These conditions not only serve to protect the patch from harsh winter temperatures, but also may partially explain the near absence of invasion by the nonnative Amur honeysuckle (*Lonicera maackii*). In contrast, Kramer

Woods has a long history of protection from direct human influences as an old-regrowth stand, but its size as a forest fragment and its site position may indirectly explain the much higher relative percentage of dieback. The 5.2 ha forest patch extends from north-to-south along two tributary streams that meet in the southeast corner. Much of the forest is therefore on slopes >10°, a setting that seems less suited for establishment by spicebush. Furthermore, the flat upland where the shrub is most abundant is along the north edge. The north edge is bordered by an open field and is an area more susceptible to tree falls and winter winds. These two factors clearly threaten the persistence of spicebush as a dominant understory shrub. In contrast to findings by Cipollini et al. (1994) that show greater performance by spicebush in tree-fall gaps, an important disturbance in beech-maple forest (Runkle 1990), the shrub does not show a spatial relationship with their occurrence in Kramer Woods. Nearly all the larger shrubs, e.g., >1.5 m, show >85% dieback. This level of disturbance may provide an opportunity for invasion by Amur honeysuckle across the north upland area. High dieback in spicebush, an indirect effect of fragmentation on the internal disturbance regime, potentially alters the understory structure and composition of the forest patch.

Between the two forest areas, Hueston Woods represents the more unique forest patch for southwestern Ohio. The natural area is one of the few stands of primeval forest near the southern edge of the beech-maple association (e.g., Ostrander 1994). Agricultural intensification and the spread of urban centers continue to isolate forests in a matrix of developed lands. Regrowth forests are typically small in size and establish in sites less suited for development, such as steeply-sloped stream corridors (Medley et al. 1995, Butalla 1995). The results from this study suggest that the topography and landscape orientation of a forest patch are correlated with the distribution and relative dieback of spicebush, a native understory shrub of the eastern deciduous forest. Unless conservation plans are directed to capture a diversity of topographic settings or incorporate buffer zones along edges, the composition and structure of these stands are predicted to change through time. The influencing mechanisms on the original forested landscape are both direct through clearing and edge effects and indirect through a change in the internal disturbance regime.

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